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(54)[Title of the Invention] Exposure Method and Exposure

Apparatus

(57) [Abstract]

[Purpose] To eliminate the movable part for the relative positional change between the sensing material and the image formed thereon, and to eliminate an alignment operation.

[Constitution] Patterns are provided on reticles by using two or more exposure wavelengths and optical filters having different transmittances to the exposure wavelengths. Also, in some cases, a photosensitive material is employed consisting of two or more types of resists having different sensitivity properties for the two or more different wavelengths.

[Scope of Claims for Patent]

[Claim 1] An exposure method in which a pattern of high resolution exceeding a resolution limit of a projection optical system can be formed by performing a plurality of times of exposures whose light intensity distributions on a photosensitive material are different, using a material whose latent image reaction density has a nonlinear sensitivity property with respect to intensity of incident light as a photosensitive material, wherein

lights having more than one different wavelengths are used as exposure light, and an original plate to be projected in which a member that selectively transmits the more than one different wavelengths is provided is illuminated.

[Claim 2] The exposure method according to claim 1 wherein

as the photosensitive material, more than one photosensitive materials having different sensitivity properties are used.

[Claim 3] A projection exposure apparatus which forms a line density distribution finer than a pattern on an original plate to be projected, using a photosensitive material whose latent image reaction density has a nonlinear sensitivity property with respect to intensity of incident light and repeating a plurality of times of exposures moving the photosensitive material and an original plate to be projected only by a predetermined amount for each exposure, the apparatus comprising:

a light source which emits more than one lights having different wavelengths as exposure light; and

an illumination optical system which illuminates the original plate to be projected with beams emitted from the light source, wherein

the original plate to be projected has a selective transmitting member which has different transmittances to the one or more wavelengths.

[Claim 4] The exposure apparatus according to claim 3 wherein

the illumination optical system has a wavelength selection means to selectively transmit the lights having different wavelengths as the exposure light.

[The Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to an exposure apparatus for producing semiconductor devices or liquid crystal plates, and more particularly to a projection-type exposure apparatus and a projection exposure method.

[0002]

[Background Art] Technology of forming a finer pattern surpassing the resolution limit of a normal batch exposure by using a material having a nonlinear sensitivity property of intensity of incident light as a photosensitive material, and performing exposure a plurality of times while changing light intensity distribution on the photosensitive material has already been disclosed in Japanese Unexamined Patent Application Publication No. Hei5-236031, by the inventors of the present invention

[0003]

[Problems to be Solved by the Invention] In the super-resolution technique previously disclosed, the reticle and the wafer had to be relatively moved each time an exposure has been performed a plurality of times. This required an operation such as to change a relative position between an original plate to be projected and a photosensitive material, or to exchange the original plate to be projected. However, an extremely accurate alignment was required in either case, and a problem arose that when the alignment became difficult, both of the cases took time, which meant that the throughput could not be improved.

[0004] In the present invention, the purpose is to remove a movable part used when a relative position change occurs between a photosensitive material and an image formed on the photosensitive material, and to eliminate the alignment operation described above.

[0005]

[Means for Solving the Problems] To solve such problems, two or more exposure wavelengths are to be used, and the pattern on the reticle is to be structured using an optical filter which has different transmittances to the two or more different exposure wavelengths. Further, in some cases, a photosensitive material consisting of two or more types of resists having different sensitivity properties to the two or more different exposure wavelengths is used.

[0006] More specifically, it is an exposure method in which a pattern of high resolution exceeding a resolution limit of a projection optical system can be formed by performing a plurality of times of exposures whose light intensity

distributions on a photosensitive material are different, using a material whose latent image reaction density has a nonlinear sensitivity property with respect to intensity of incident light as a photosensitive material, wherein lights having more than one different wavelengths are used as exposure light, and an original plate to be projected in which a member that selectively transmits the more than one different wavelengths is provided is illuminated.

[0007] Further, as the photosensitive material, more than one photosensitive materials having different sensitivity properties are used. Furthermore, a projection exposure apparatus is proposed that forms a line density distribution finer than a pattern on an original plate to be projected, using a photosensitive material whose latent image reaction density has a nonlinear sensitivity property with respect to intensity of incident light and repeating a plurality of times of exposures moving the photosensitive material and an original plate to be projected only by a predetermined amount for each exposure, the apparatus comprising: a light source which emits more than one lights having different wavelengths as exposure light; and an illumination optical system which illuminates the original plate to be projected with beams emitted from the light source, wherein the original plate to be projected has a selective transmitting member which has different transmittances to the one or more wavelengths.

[0008]

[Operation] An operation of the present invention will be described, based on a first embodiment according to the present invention shown in FIGS. 2 and 3. Different exposure wavelengths

$\lambda 1$ and $\lambda 2$ are used, and a one-dimensional periodic pattern is used as an original plate 30 to be projected as shown in FIG. 2. Furthermore, the periodic pattern is structured in such a manner that a portion 31 which transmits the exposure wavelength $\lambda 1$ and does not transmit the exposure wavelength $\lambda 2$ and a portion 32 which does not transmit the exposure wavelength $\lambda 1$ and transmits the exposure wavelength $\lambda 2$ are alternately arranged. Using this original plate to be projected, a light intensity distribution upon projection with the exposure wavelength $\lambda 1$ is inverted by 180°relative to a light intensity distribution upon projection with the exposure wavelength $\lambda 2$ on the image plane, as shown in FIG. 3. Namely, the light intensity distributions inverted in bright and dark portions can be formed without necessitating any mechanical shift.

[0009] A generally effective technique to increase degrees of freedom of the pattern on the original plate to be projected is addition of a portion that transmit both wavelengths $\lambda 1$ and $\lambda 2$ and a portion that transmit neither $\lambda 1$ nor $\lambda 2$ to the portion which transmits $\lambda 1$ and does not transmit $\lambda 2$ and the portion which does not transmit $\lambda 1$ and transmits $\lambda 2$. Also, for exposure of a complex pattern, it is generally required to form a light intensity distribution completely independent of the wavelengths $\lambda 1$ and $\lambda 2$. In such a case, it can be considered that formation of a pattern with a plurality of portions could be complicated as shown in FIG. 4. While the pattern is not so complicated for two wavelengths, it becomes greater and greater for three or more wavelengths. Then, if a synthetic photosensitive material comprising two or more types of photosensitive materials having different sensitivity

properties for two wavelengths is used as the photosensitive material, a pattern can be formed more easily.

[0010] A synthetic photosensitive material is employed consisting of two or more types of photosensitive materials having different sensitivity properties, for example, a photosensitive material sensitive to the wavelength λ1 but not sensitive to other wavelengths and a photosensitive material sensitive to the wavelength λ2 but not sensitive to other wavelengths. In this case, illumination with wavelength λ1 causes only the λ1 transmitting portion on the original plate to be projected to transmit the light, which forms a first light intensity distribution. Next, illumination with wavelength λ2 causes only the λ2 transmitting portions to transmit the light, regardless of the transmission of the λ1, and the light forms a second light intensity distribution. These first and second light intensity distributions make two components contained in the synthetic photosensitive material be exposed independently of each other.

[0011]

[Embodiment] FIG. 1 is a drawing which shows an entire schematic structure of an exposure apparatus in the present invention. A beam of illumination light from a light source 11 which can emit beams of two or more different wavelengths is collected by an elliptic mirror 12 and then guided by a mirror 13 into a collimator lens 14, where the beam becomes a bundle of nearly parallel rays. The beam then passes through an interference filter 21, which serves as a wavelength selecting means detachably arranged, then enters a fly's eye integrator 15. Beams emergent from the fly's eye integrator 15 are guided

by a mirror 16 into a main condenser 17 to uniformly illuminate a reticle 18 serving as an original plate to be projected. A predetermined pattern on the original plate 18 to be projected is projected by a projection optical system 19 onto a wafer 20 coated with a photosensitive material. By exchanging the interference filter 21 for another filter having a different wavelength property as shown by the arrows in the drawing, the wavelength $\lambda 1$ is selected as the exposure wavelength for a first exposure and the wavelength $\lambda 2$ for a second exposure. Here, it is a matter of course that the projection optical system 19 is arranged to have no chromatic aberration for the two wavelengths $\lambda 1$ and $\lambda 2$.

[0012] Incidentally, while the interference filter 21 was placed to be located in the illumination optical system between the collimator lens 14 and the fly's eye integrator 15 in this case, the interference filter 21 can be located at any position in the exposure apparatus as long as it does not affect the imaging performance there. Furthermore, it is of course possible that, instead of the interference filter 21 located in the exposure apparatus, means such as a dichroic mirror or a glass filter and the like having absorption property can be used to select the exposure wavelength $\lambda 1$ for the first exposure and the exposure wavelength $\lambda 2$ for the second exposure.

[0013] As described previously, FIG. 2 is a drawing which shows a schematic cross section of a structure of a reticle in the first embodiment, which is an enlarged drawing of reticle 18 serving as the original plate to be projected in FIG. 1. On a reticle substrate 33, a one-dimensional periodic pattern is formed of an optical thin film which structures an interference

filter. As shown in FIG. 2, the portion 31 (hatched portion) having characteristics of transmitting λ1 and not transmitting λ2 and the portion 32 (dotted portion) having opposite characteristics of not transmitting λ1 and transmitting λ2 are alternately arranged in the same width. When this reticle pattern is illuminated first with illumination light of wavelength λ1 and then with illumination light of λ2, periodic patterns are formed in light intensity distributions with bright and dark portions inverted between the two wavelengths, as shown in FIG. 3. Under such circumstances, a fine pattern surpassing the resolution limit can be obtained by using a photosensitive material having the non-linear sensitivity property of latent image reaction density against intensity of incident light with the wavelengths λ1 and λ2.

[0014] The above embodiment showed an example where the reticle serving as the original plate to be projected had the one-dimensional periodic pattern. However, normal reticles rarely have such a simple arrangement of an one-dimensional periodic pattern, but often have complex patterns. Thus, a second embodiment is given as an example where degrees of freedom of usable patterns are increased by adding portions transmitting both the wavelengths and portions transmitting neither of the two wavelengths on the pattern. FIG. 4 shows a cross section of a reticle employed in the second embodiment. The reticle 40 has a portion 41 (dotted portion) having characteristics of transmitting λ1 and not transmitting λ2, and a portion 42 (hatched portion) having opposite characteristics of not transmitting λ1 and transmitting λ2, which are alternately arranged, and furthermore has additional portions

which are a perfectly opaque portion 43 (black portion) not transmitting either λ1 or λ2 on the left end side and a perfectly transparent portion 44 (white portion) transmitting both λ1 and λ2 on the right end side. Patterns of light intensity distributions as shown in FIG. 5 are obtained upon image formation with respective illumination light of wavelengths λ1 and λ2 using the reticle.

[0015] Under such circumstances, a fine pattern surpassing the resolution limit can be obtained using a photosensitive material having the non-linear sensitivity property of latent image reaction density against intensity of incident light of wavelengths λ1 and λ2. Further, hereinafter described is a third embodiment employing a resist which is a synthetic photosensitive material obtained by mixing a photosensitive component 1 sensitive only to the wavelength λ1 with a photosensitive component 2 sensitive only to the wavelength λ2.

[0016] FIG. 6 is a drawing which shows a schematic cross section of a structure of a reticle used in the third embodiment. The reticle 60 is arranged so that a first pattern is formed of an optical thin film 62 having characteristics of not transmitting only the wavelength λ1 and transmitting wavelengths other than the wavelength λ1 on a reticle substrate 61, a second pattern is formed of an optical thin film 63 having characteristics of not transmitting only the wavelength λ2 and transmitting wavelengths other than the wavelength λ2 on the substrate, and with superposition of the two patterns the photosensitive component 1 in the resist forms only a latent image of the first pattern while the photosensitive component 2 forms only a latent image of the second pattern. Since the resist has the nonlinear

sensitivity property of latent image reaction density against the intensity of incident light, a fine pattern surpassing the resolution limit can be obtained.

[0017] Incidentally, it is clear that this technique can be applied to cases where three or more types of exposure wavelengths are employed. It is preferred that the two reticle patterns 62 and 63 shown in FIG. 6 be formed at a suitable clearance with a transparent member 64 in between. The clearance is preferably set as small as possible if the spectral characteristics necessary for the reticle 60 are satisfied. More preferably, the clearance is within the depth of focus of the projection optical system. However, even if the clearance is not within the depth of focus, exposure is possible with slight correction of the focus position. This case also keeps the features of the present invention.

[0018] Furthermore, described hereinafter is a fourth embodiment using two different monochromatic light sources and a resist which is a synthetic photosensitive material obtained by mixing two photosensitive components different in wavelength sensitivity property with each other. Here, $\lambda 1$, $\lambda 2$, $\lambda 3$, $\lambda 4$, $\lambda 5$, and $\lambda 6$ are wavelengths increasing in the named order, and the wavelengths are different from each other. The light sources employed in the present embodiment are a laser L1 emitting monochromatic light of wavelength $\lambda 2$ and a laser L2 emitting monochromatic light of wavelength $\lambda 5$, which are arranged to emit rays of mixture of these chromatic light beams onto a reticle.

[0019] The reticle consists of a one-dimensional periodic pattern in which a portion having characteristics of

transmitting only wavelengths near the wavelength λ2 and not transmitting the wavelengths other than the wavelength λ2 and a portion having characteristics of transmitting the wavelengths near the wavelength λ5 and not transmitting wavelengths other than the wavelength λ5 are alternately formed in a same width on a reticle substrate. A resist employed herein is a synthetic photosensitive material consisting of a photosensitive component 1 having a sensitivity to the range of from wavelength λ1 to λ3 and a photosensitive component 2 having a sensitivity to the range of from wavelength λ4 to λ6, formed on the substrate as shown in FIG. 7.

[0020] Upon full exposure using the resist and the two monochromatic light sources, because the photosensitive component 1 is sensitive to the wavelength λ2 but not sensitive to the wavelength λ5, an image of a light intensity distribution formed by the wavelength λ2 serves as a latent image, regardless of a light intensity distribution formed by the wavelength λ5. Conversely, the photosensitive component 2 is sensitive to the wavelength λ5 but not sensitive to the wavelength λ2, and, therefore, the image of the light intensity distribution formed by the wavelength λ5 serves as the latent image, regardless of the light intensity distribution formed by the wavelength λ2. Since the resist has the nonlinear sensitivity property of the latent image reaction density against the intensity of incident light, a fine pattern surpassing the resolution limit can be obtained.

[0021] Although the full exposure was carried out at the same time using the different wavelengths in the fourth embodiment, it is of course possible that exposure can be made for each

wavelength in a non-simultaneous manner. As well as the resist with photosensitive component 1 and photosensitive component 2 having the wavelength sensitivity characteristics in which the wavelengths increase in the above order of λ1, λ2, λ3, λ4, λ5, and λ6, the same results as the fourth embodiment can be obtained using a resist where λ4 (the short wavelength edge of the photosensitive component 2)<λ3 (the long wavelength edge of the photosensitive component 1), if λ4 (the short wavelength edge of photosensitive component 2)>λ2 (the exposure wavelength from laser L1) and if λ5 (the exposure wavelength from laser L2)>λ3 (the long wavelength edge of photosensitive component 1).

[0022]

[Advantageous Effect of the Invention] According to the present invention, two or more independent images can be thus formed on a photosensitive material without performing a horizontal shift of a reticle or a wafer or a reticle exchange that require accurate positioning, thus considerably decreasing the necessity of exchanging the original plate to be projected.

[Brief Description of Drawings]

[FIG. 1] An exposure apparatus of the present invention.

[FIG. 2] A sectional view showing a schematic structure of a reticle in a first embodiment.

[FIG. 3] A light intensity distribution on an image plane in the first embodiment.

[FIG. 4] A sectional view showing a schematic structure of a reticle in a second embodiment.

[FIG. 5] A light intensity distribution on an image plane in

the second embodiment.

[FIG. 6] A sectional view showing a schematic structure of a reticle in a third embodiment.

[FIG. 7] A view showing wavelength characteristics of a photosensitive material in a fourth embodiment.

DRAWINGS

[FIG. 2]

[FIG. 3]

LIGHT INTENSITY

INTENSITY DISTRIBUTION OF λ2

INTENSITY DISTRIBUTION OF λ1

POSITION

[FIG. 1]

[FIG. 5]

LIGHT INTENSITY

POSITION

[FIG. 7]

SENSITIVITY

WAVELENGTH

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